

01/23/98

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**UTILITY
PATENT APPLICATION
TRANSMITTAL**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.

19536-706-00 US

Total Pages

25

First Named Inventor or Application Identifier

Mitch Prater

Express Mail Label No.

EH592703015US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents:

Assistant Commissioner for Patents

ADDRESS TO: Box Patent Application
Washington, DC 202311. ☒ Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)2. ☒ Specification [Total Pages 10]
(preferred arrangement set forth below)

- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. ☒ Drawings (35 USC 113) [Total Sheets 10]

4. Oath or Declaration [Total Pages 2]

a. ☒ Newly executed (original or copy)
(unexecuted)b. ☐ Copy from a prior application (37 CFR 1.63(d))
(for continuation/divisional with Box 17 completed)

[Note Box 5 below]

i. ☐ **DELETION OF INVENTOR(S)**
Signed statement attached deleting inventor(s) named in
the prior application, see 37 CFR 1.63(d)(2) and 1.33(b)5. ☐ Incorporated By Reference (useable if Box 4b is checked) The entire
disclosure of the prior application, from which a
copy of the oath or declaration is supplied under Box 4b,
is considered as being part of the disclosure of the accompanying
application and is hereby incorporated by reference therein.6. ☐ Microfiche Computer Program (Appendix)7. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)a. ☐ Computer Readable Copyb. ☐ Paper Copy (identical to computer copy)c. ☐ Statement verifying identity of above copies**ACCOMPANYING APPLICATION PARTS**8. ☐ Assignment Papers (cover sheet & document(s))9. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney
(when there is an assignee)10. ☐ English Translation Document (if applicable)11. ☐ Information Disclosure ☐ Copies of IDS
Statement (IDS)/PTO-1449 Citations12. ☐ Preliminary Amendment13. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)14. ☐ Small Entity ☐ Statement filed in prior application,
Statement(s) Status still proper and desired15. ☐ Certified Copy of Priority Document (s)
(if foreign priority is claimed)16. ☒ Other: Declaration (Box 4a.) is unexecuted17. If a CONTINUING APPLICATION,
check appropriate box and supply the requisite information:☐ Continuation ☐ Divisional ☐ Continuation-in-part
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of prior application No: _____ / _____

18. CORRESPONDENCE ADDRESS☐ Customer Number or Bar Code Label

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Correspondence address below

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AB980210.063/19536-706

01/23/98

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Patent fees are subject to annual revision on October 1.
These are the fees effective October 1, 1997.
Small Entity payments must be supported by a small entity statement,
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TOTAL AMOUNT OF PAYMENT (\$) 790.00

Complete if Known

Application Number	Unassigned
Filing Date	Unassigned
First Named Inventor	Mitch Prater
Examiner Name	Unassigned
Group / Art Unit	Unassigned
Attorney Docket No.	19536-706-00 US

METHOD OF PAYMENT (check one)

1. ☒ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number 13-0257
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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101 790	201 395	Utility filing fee	\$790
106 330	206 165	Design filing fee	
107 540	207 270	Plant filing fee	
108 790	208 395	Reissue filing fee	
114 150	214 75	Provisional filing fee	
SUBTOTAL (1)			(\$) 790.00

2. EXTRA CLAIM FEES

Total Claims	Extra Claims	Fee from below	Fee Paid
Independent Claims	-20** =	X	
Multiple Dependent	-3** =	X	

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
103 22	203 11	Claims in excess of 20
102 82	202 41	Independent claims in excess of 3
104 270	204 135	Multiple dependent claim, if not paid
109 82	209 41	** Reissue independent claims over original patent
110 22	210 11	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$) 790.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	
127 50	227 25	Surcharge - late provisional filing fee or cover sheet.	
139 130	139 130	Non-English specification	
147 2,520	147 2,520	For filing a request for reexamination	
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	
115 110	215 55	Extension for reply within first month	
116 400	216 200	Extension for reply within second month	
117 950	217 475	Extension for reply within third month	
118 1,510	218 755	Extension for reply within fourth month	
128 2,060	228 1,030	Extension for reply within fifth month	
119 310	219 155	Notice of Appeal	
120 310	220 155	Filing a brief in support of an appeal	
121 270	221 135	Request for oral hearing	
138 1,510	138 1,510	Petition to institute a public use proceeding	
140 110	240 55	Petition to revive - unavoidable	
141 1,320	241 660	Petition to revive - unintentional	
142 1,320	242 660	Utility issue fee (or reissue)	
143 450	243 225	Design issue fee	
144 670	244 335	Plant issue fee	
122 130	122 130	Petitions to the Commissioner	
123 50	123 50	Petitions related to provisional applications	
126 240	126 240	Submission of Information Disclosure Stmt	
581 40	581 40	Recording each patent assignment per property (times number of properties)	
146 790	246 395	Filing a submission after final rejection (37 CFR 1.129(a))	
149 790	249 395	For each additional invention to be examined (37 CFR 1.129(b))	
Other fee (specify)			
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SUBMITTED BY

Typed or Printed Name J. David Hadden

Signature

J. David Hadden

Date

1/23/98

Complete (if applicable)

Reg. Number 40,629

Deposit Account User ID

PSEUDO AREA LIGHTS

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January 23, 1998


R.L. Brandes

PSEUDO AREA LIGHTS

FIELD OF THE INVENTION

The invention relates generally to the art of computer graphics and animation.

- 5 More particularly, the invention relates to efficient approximation of finite light sources using point light sources of varying location and intensity.

BACKGROUND OF THE INVENTION

10 In order to render a scene in computer graphics or computer animation, computer artists and animators often will place one or more light sources within the scene in order to illuminate it. If, for instance, an animator wished to render a room that was lit by two light bulbs, he or she would construct two light sources, representing the light bulbs, and then calculate the illumination effect of these two sources. The standard construct for such directional light sources is the point source, whereby all light is considered to emanate from a single point.

15 The point source is the standard construct because calculation of its illumination effect is computationally straightforward. For any given surface point within the scene, the rendering method need only calculate the effect of a single ray of light, which has a singular direction and intensity. The disadvantage of using the point source is its lack of realism. When illuminated by a point source, any surface point in the scene will either be illuminated by the point light source, or else wholly hidden from it. As a result, shadows and other partial lighting conditions are rendered in an unrealistically sharp, binary manner (see Figure 5).

25 One alternative to using a point light source is to use a finite source, one that has an extended shape and size. The light emerging from a finite source will emanate from its entire surface, and not just a single point. Finite sources illuminate a scene in a much more realistic manner. Some surface points will be illuminated by the entire finite light source, others totally hidden from it. More important is the fact that some points will be partially illuminated by the source.

Despite this superior effect, computer artists and animators do not currently use finite light sources to illuminate their graphics and their scenes. Determination of the total contributing light from a finite light source to a surface point, has, till this point, required a numerical integration over the entire surface of the finite source. Such calculations are simply too cumbersome to be practically used in computer animation. Finite light sources are sometimes used to illuminate single computer-generated scenes or "photos" when a highly realistic image is desired and computational speed is not an issue, but even in these situations the computational burden is considered onerous.

Computer artists and animators run into analogous problems when attempting to simulate ambient light such as skylight. Realistic calculations with respect to simulated ambient light sources are also too cumbersome to make them practical. The conventional technique for simulating ambient light, therefore, is to simply turn up the brightness throughout an entire scene, with perhaps gross modifications for surfaces points that obviously will be differentially affected by the light (such as those under dark shadows). The computation required for this is straightforward, even trivial, but the illumination effect is again not very realistic.

SUMMARY OF THE INVENTION

The invention relates to a method for approximating the illumination effect of a finite light source by a using a point light source of varying intensity and location. These two variables are manipulated depending on the "visibility" of the finite light source from the perspective of the surface point being rendered. The result is realistic illumination with minimal computational effort.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows generally the elements of a computer system suitable for carrying out the present invention.

FIG. 2 shows the main steps involved in rendering a computer-animated scene.

5 FIG. 3 shows the main steps involved in rendering the surfaces within a computer-animated scene.

FIG. 4 shows the main steps involved in illuminating and shading a rendered surface within a computer-animated scene.

10 FIG. 5 shows illustrates the problem of unrealistically sharp shadows created by a point light source.

FIG. 6 shows the "terminator region" of partial illumination on an object surface.

FIG. 7 shows the method for choosing a point light source based upon the surface point in question, which results in a particular light vector direction

15 FIG. 8 shows the method for determining the light intensity based upon the portion of the finite light source which is hidden.

FIG. 9 shows two examples of pseudo-centers used to calculate light vector directions for given points in the terminator region.

20 FIG. 10 shows the method of determining the light intensity and light vector direction for a given point under an infinite hemisphere of light, based upon the known tangent plane and normal.

DETAILED DESCRIPTION OF TWO EXEMPLARY EMBODIMENTS: FINITE LIGHT SOURCE APPROXIMATION AND INFINITE HEMISPHERE ILLUMINATION

Figure 1 shows a computer system suitable for carrying out the invention. A main
5 bus 1 is connected to one or more CPUs 2 and a main memory 3. Also connected to the bus are a
keyboard 4 and large disk memory 5. The frame buffer 6 receives output information from the
main bus and sends it through another bus 7 to either a CRT or another peripheral which writes
the image directly onto film. The computer system is used to approximate the illumination effect
of a finite light source and an infinite hemisphere light source. The main steps in carrying out
10 the rendering and illumination of a scene are shown in Figures 2-4.

One exemplary embodiment of the invention involves use of a directional light
source for general illumination within a scene. Such a light source might be the only light source
within a scene, it might be the primary source (supplemented by secondary light sources) or it
might be one of a number of primary light sources (such as a number of simulated light bulbs).

15 Figure 6 shows a spherical light source illuminating the surface of an object.
Spheres are perhaps the most useful shapes to use as light sources because they create an
illumination effect similar to that of many real-life directional light sources, such as light bulbs.
Computation of their illumination effect, whether by explicit integration or approximation, as in
the described invention, is also usually simpler than it is with other shapes. The object to be
20 illuminated is, for illustrative purposes, also shown as a sphere.

With respect to the top of the illuminated object, we can draw two tangents
between the light sphere and the object, defining points P_0 and P_1 . Points to the right of P_0 are
wholly hidden from the light sphere, and thus not illuminated. Points to the left of P_1 are wholly
illuminated, which means they receive the total illumination of the light sphere. Calculation of
25 both the light intensity and the light vector direction for these points is straightforward (light
intensity being some chosen function and vector direction being the vector between the center of
the light sphere, C , and the point P being considered).

The points P_0 and P_1 define a terminator region, within which all points are partially illuminated by the light sphere (note that this terminator region is actually an extended band that circles the sphere, with points analogous to P_0 and P_1 defining its boundaries). N_0 and N_1 are the corresponding normals at those points. Determining the illumination effect by radiosity analysis for each of these points would require a numerically complex integration over the portion of the light sphere that illuminates the points. The described invention approximates these calculations with results that are almost indistinguishable from the numerically complex integration.

Figure 7 shows a tangent plane, T_s , drawn from one of the points P in the terminator region to the light sphere. The tangent plane can be extended further, so that it cuts through the light sphere. Viewed from the side, plane T_s appears as a tangent line (see Figure 7). The portion of the projected disk that is above T_s is above the "horizon line" as seen from point P , and thus considered to shine upon that point. The portion of the light sphere below T_s is below the horizon line, and thus considered hidden from point P .

Comparing T_s with the line drawn from point P to the center of the light sphere, line P_s , it follows that θ , the angle between T_s and P_s , is $\arccos(-P_s \cdot N) - \pi/2$ and that D , the distance between the center of the light sphere and the line T_s , is $\tan(\theta) \times P_s$. The vector direction of the light from the truncated sphere to the object can be approximated by creating a "pseudo-center" X with respect to the light sphere. Pseudo-center X is determined by shifting the center of the light sphere, C , a distance D in the direction given by the vector $P_s \times (N \times P_s)$. The vector from this newly defined X to point P defines the vector direction of light used to illuminate point P (see Figure 7).

The intensity of light reaching the point P will depend on the area of the projection of the truncated light source on a plane perpendicular to the line P_s . That area can in turn be approximated by the area of the truncated sphere projected onto the plane perpendicular to the tangent plane T_s containing the line P_s which is the projection shown in Figures 7 and 8. The intensity of the constructed point source at X that is used to illuminate point P in the terminator region is thus calculated as a function of the portion of the light sphere that is above

the horizon, which is also determined from D. We can see in Figure 8 that the areas of the light sphere visible from point P are areas Z, A and A'. Area Z is simply one-half the area of the disk. Area A is the sum of areas F and G, and the area of A' = A. The area of F is $D(R^2 - D^2)^{1/2}/2$ and the area of G is $[R^2 \arcsin(D/R)]/2$. These trigonometric calculations can in practice be approximated by the function $T^2(3-2T)$, where T is defined as $(D+R)/2R$.

The described invention thus uses a point light source of varying location and intensity to approximate the effect of a finite light source. Figure 9 shows the pseudo-center X, standing alone as a point source, in order to illuminate point P. Figure 9 also shows another pseudo-center X' derived by the same method and used to illuminate point P'. The invention achieves an illumination effect similar to that of true radiosity analysis at a computational cost comparable to that required for a point source.

Note that in this embodiment of the invention, the vector direction of the light is drawn from the pseudo-center X, and not from some pseudo-surface point at a given radius as one might expect. This simplification helps reduce the computational load. When the radius of the finite light source is small compared to the distance between the source and the surface it illuminates, the simplification does not diminish the realism of the effect.

A second exemplary embodiment of the invention is used to simulate ambient light such as skylight. This embodiment first requires the construction of a lighted hemisphere of infinite radius within a scene. The illumination effect of the hemisphere is then approximated using point sources of varying location to achieve a realistic light effect.

In Figure 10, we can see the lighted hemisphere that encloses the animated scene like a dome, as well as a point P within that scene. To determine the intensity of ambient light that shines upon that point, we first derive the tangent plane and the normal vector, N, to that point (usually from the function that is used to draw P). If we extend this tangent plane so that it reaches out to infinity and intersects the hemisphere, we can see that only a portion of the hemisphere can actually shine light upon point P. That fraction is $1 - \arccos(N \cdot L)$, where L is a vector that points toward a chosen "pole" of the hemisphere. The intensity is a simple (usually direct) function of that portion.

The vector direction of light shining upon point P is determined by using the centroid of that portion of the hemisphere cut by the tangent plane. In Figure 10, we see the centroid O, which is determined by the vector addition of N and L. This centroid then acts a point light source with respect to point P. The vector from O to P defines the vector direction of light. The infinite radius of the light hemisphere serves as a fiction to determine the position of the point O.

The specific arrangements and methods described herein are merely illustrative of the principles of the present invention. Numerous modifications in form and detail may be made by those of ordinary skill in the art without departing from the scope of the present invention. Although this invention has been shown in relation to particular embodiments, it should not be considered so limited. Rather, the present invention is limited only by the scope of the appended claims.

CLAIMS

What is claimed is:

1. A method for illuminating surfaces in computer graphics comprising the steps of:
 - constructing one or more finite light sources within a computer animated scene, each of the finite light sources having a finite size and a center;
 - constructing a plurality of surfaces with the scene, each surface consisting of a plurality of points; and
 - approximation of the illumination effect of each of the finite light sources by the use of a plurality of point light sources of varying intensity.
2. The method of claim 1 wherein a portion of each of the light sources illuminates each of the points.
3. The method of claim 2 comprising the further step of approximately calculating a light intensity and a light vector direction as a function of the portion of each of the light sources which illuminates each of the points.
4. The method of claim 3 comprising the further step of calculating the light intensity as a function of the portion of the light source which illuminates each of the points.
5. The method of claim 4 comprising the further step of approximating the light vector direction as a function of the portion of the light source shines upon the point.
6. The method of claim 1 wherein said finite light source is a sphere.

1 7. A method for illuminating surfaces in computer graphics comprising the
2 steps of:

3 constructing a hemispherical light source of infinite radius;

4 constructing a plurality of surfaces with said scene, said surfaces
5 consisting of a plurality of points.

6 approximation of the illumination effect of each of the hemispherical light
7 source by the use of a plurality of point light sources.

1 8. The method of claim 7, comprising the further step of calculating a light
2 intensity and a light vector direction as a function of a portion of the light source which
3 illuminates each of the points.

1 9. The method of claim 8 wherein said light vector direction is a function of the
2 portion of said hemispherical light source which shines upon said point.

1 10. The method of claim 9 wherein said light intensity is a function of the portion
2 of said hemispherical light source which shines upon said point.

ABSTRACT

Computer animators have, till now, largely relegated themselves to using point light sources when simulating directional light sources in computer graphics and animation. The illumination achieved is computationally feasible but not totally realistic. While it is possible to use a finite light source of given size and shape to achieve a more realistic effect, the radiosity analysis required to calculate the illumination effect of such a light source is so cumbersome that it cannot be used for real-time computer animation. The described invention allows the animator to approximate the illumination effect of a finite light source by using a point source of varying location and intensity. Another embodiment of the invention allows the animator to realistically simulate ambient light by a similar method. The resulting illumination effects are comparable to those achieved with full radiosity analyses at much lower computational loads.

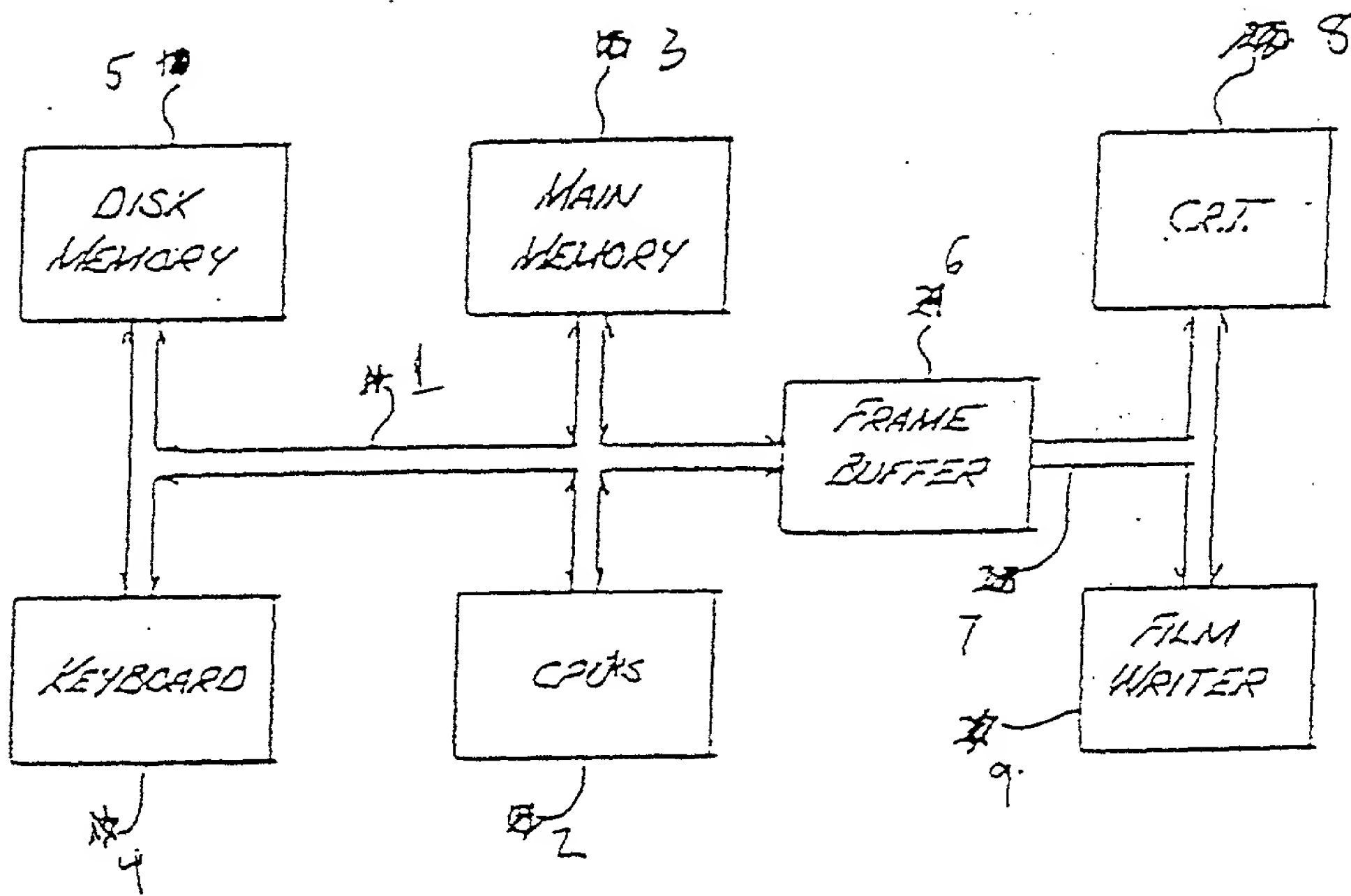


FIG. 1

Rendering Process

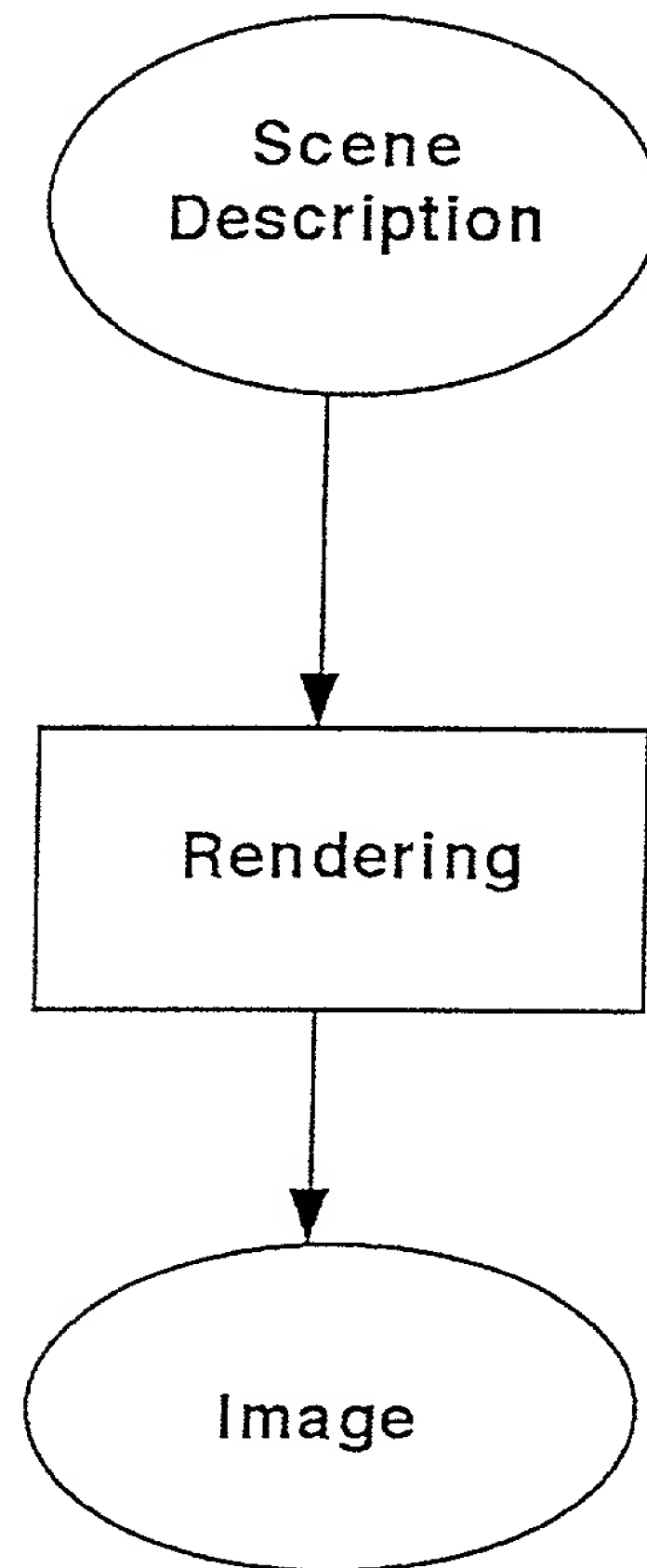


FIG. 2

Rendering

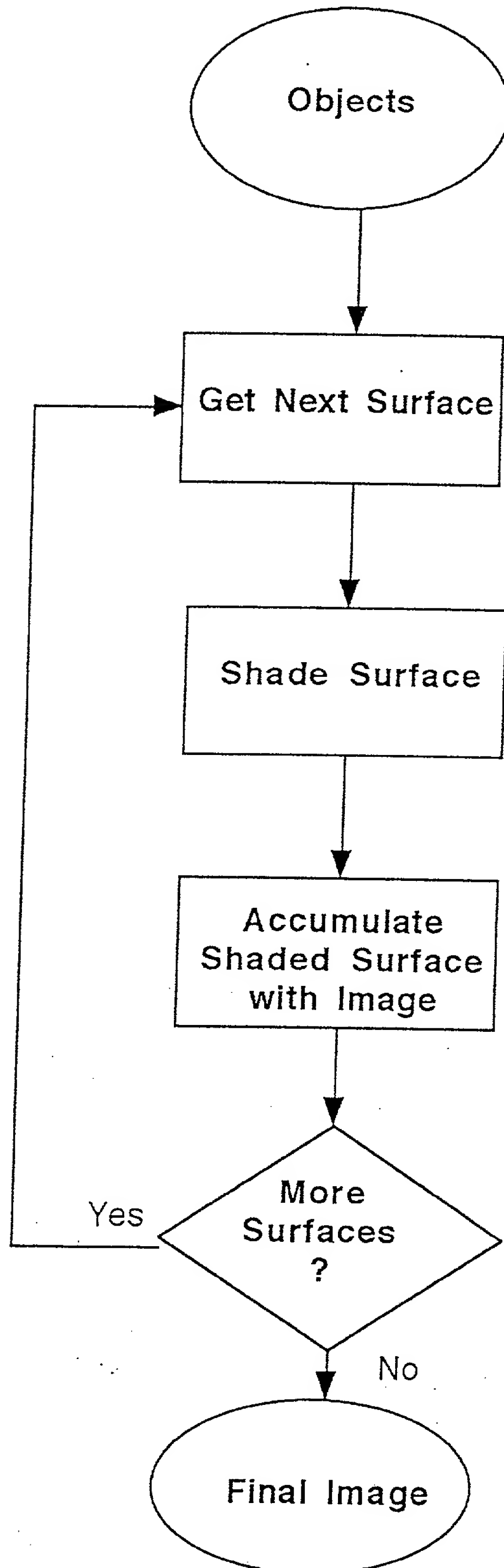
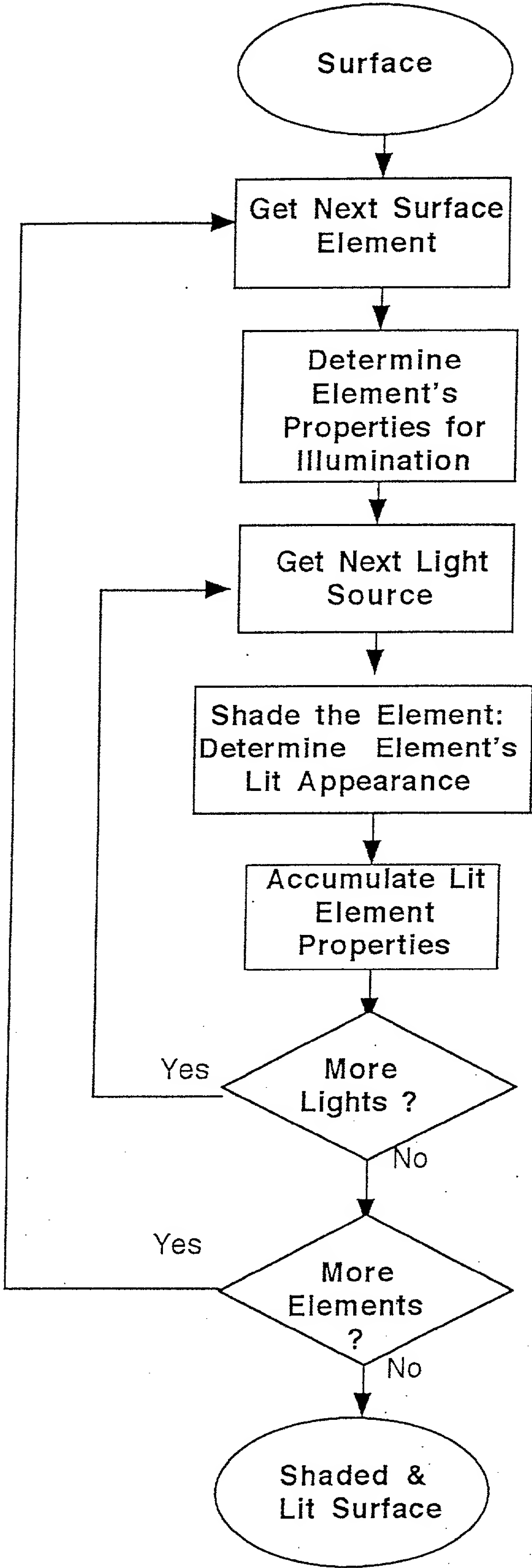


FIG 3

Shade Surface



Determine the surface element visual properties irrespective of any illumination. Then combine this result with the influence of illumination from the light source.

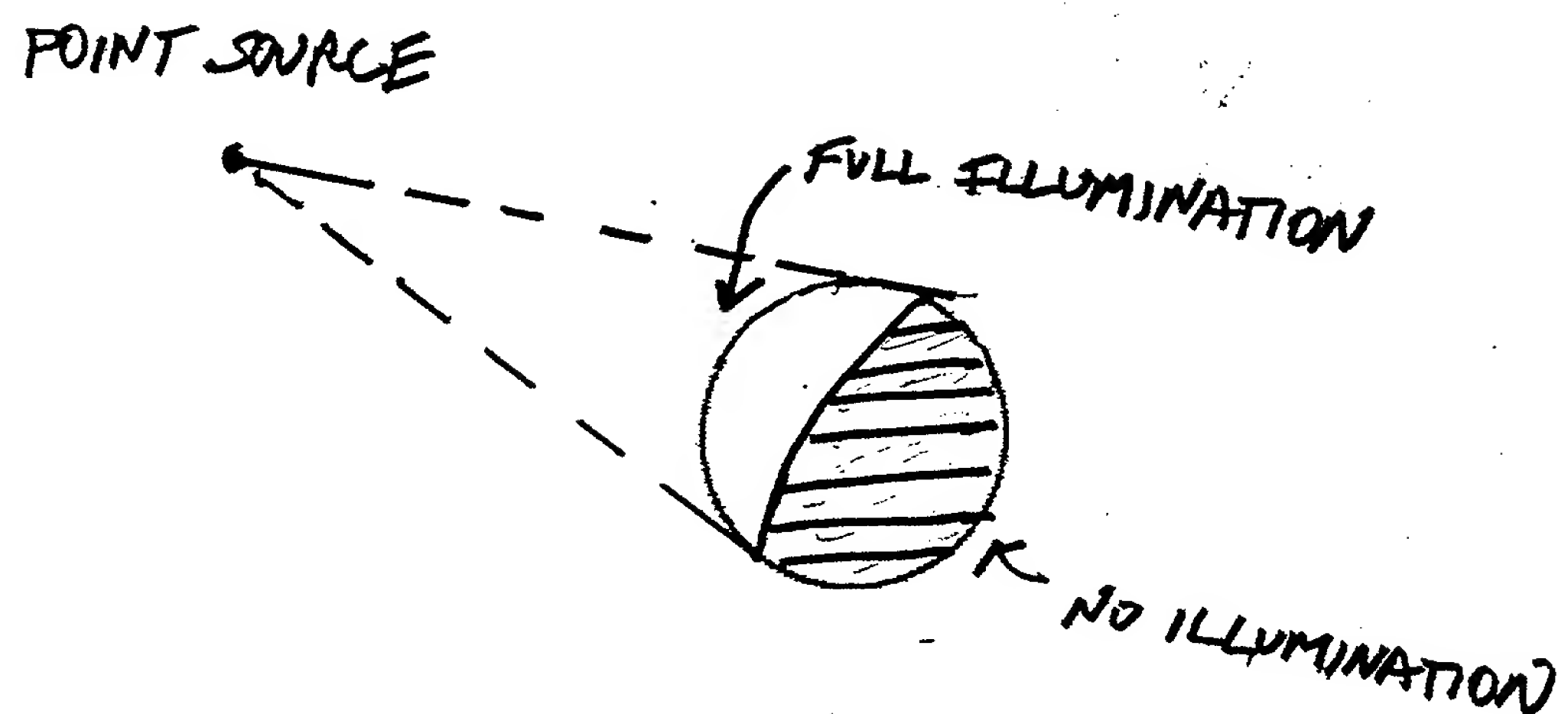
[illegible]

FIG. 5

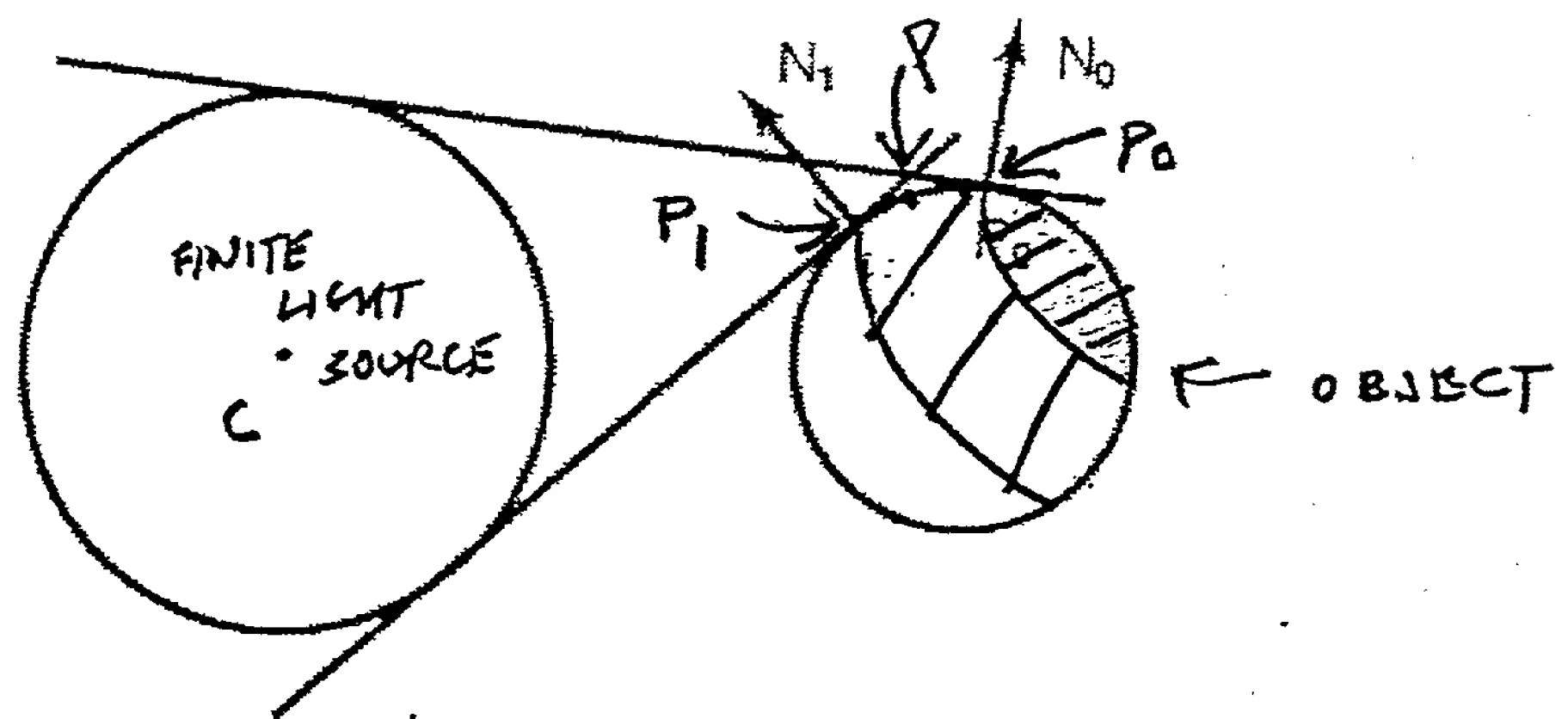


FIG. 6

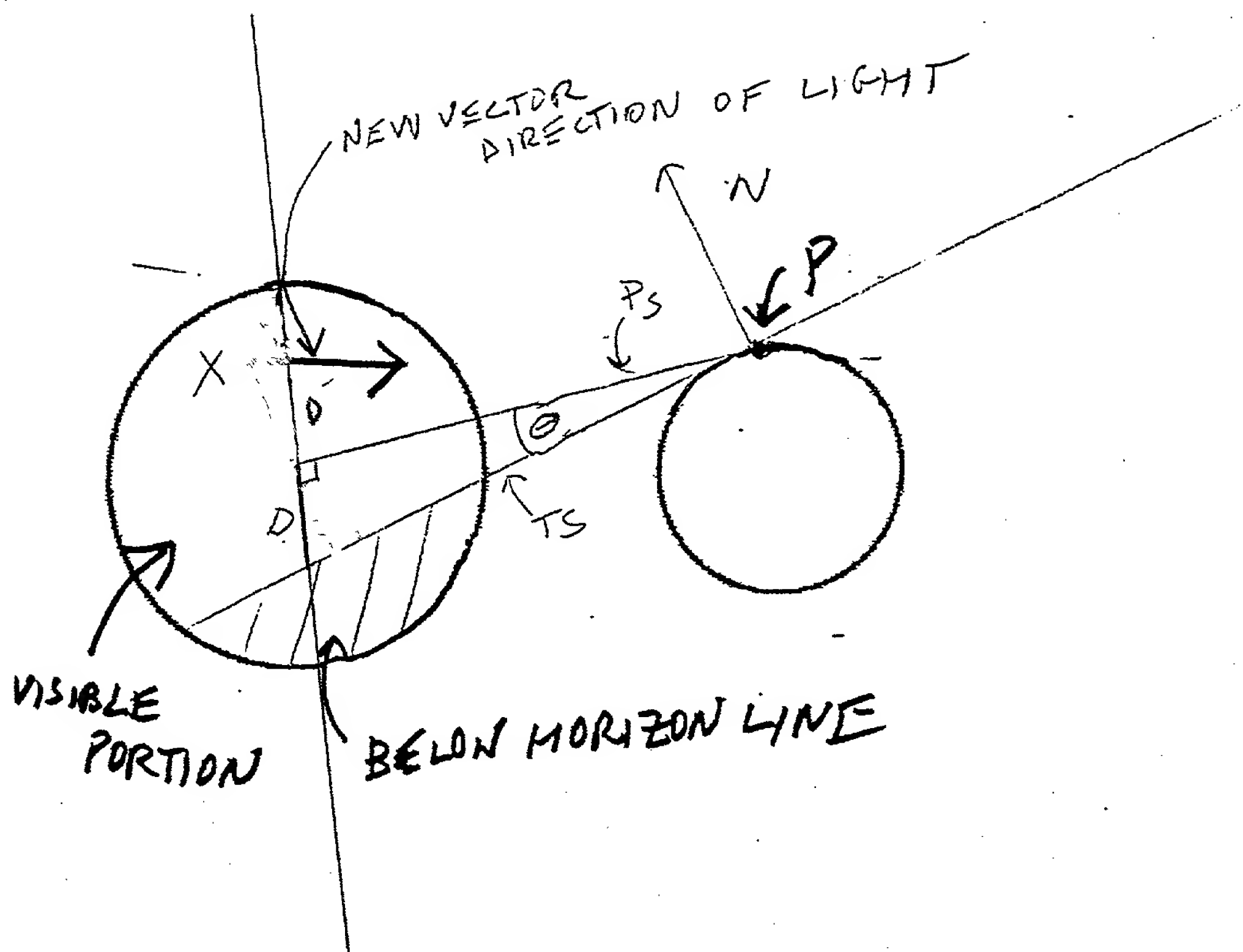
[illegible]

FIG. 7

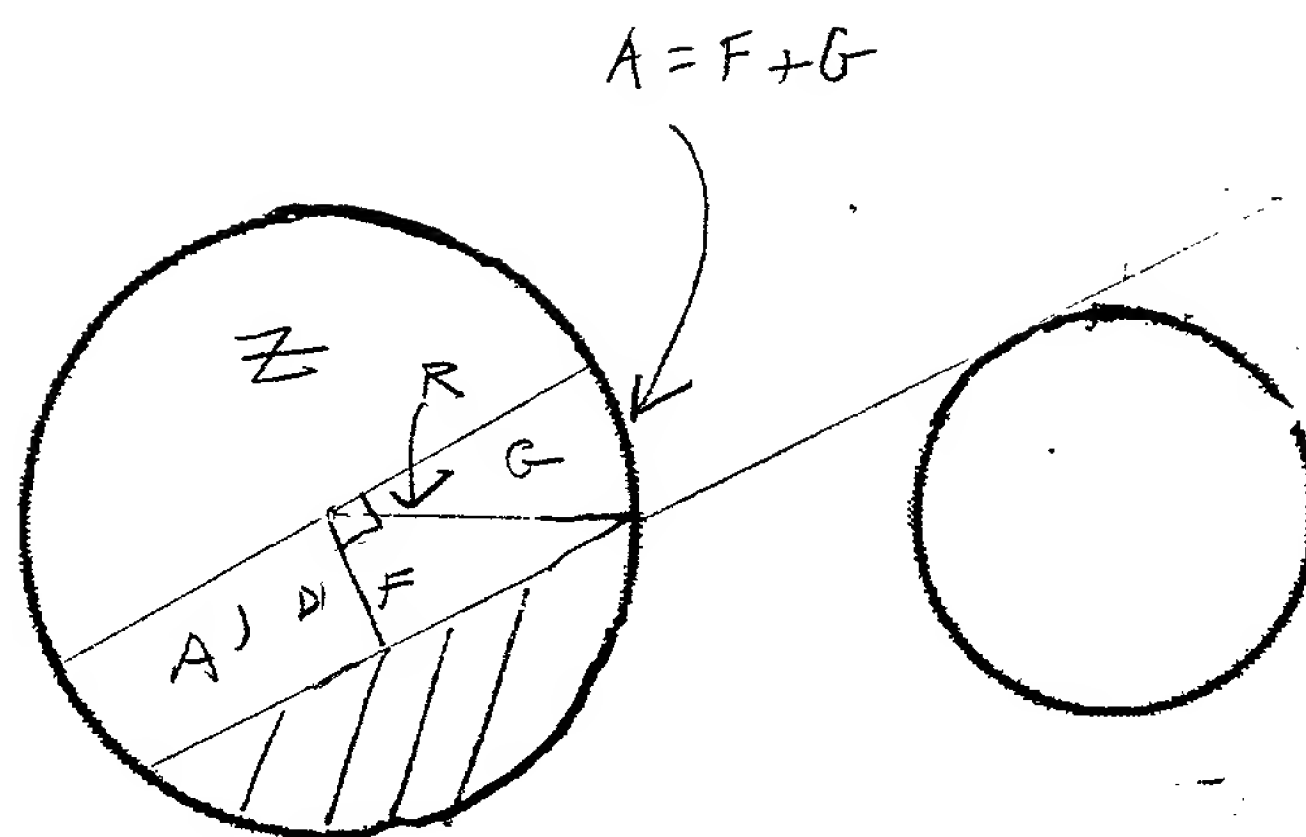
[illegible]

FIG. 8

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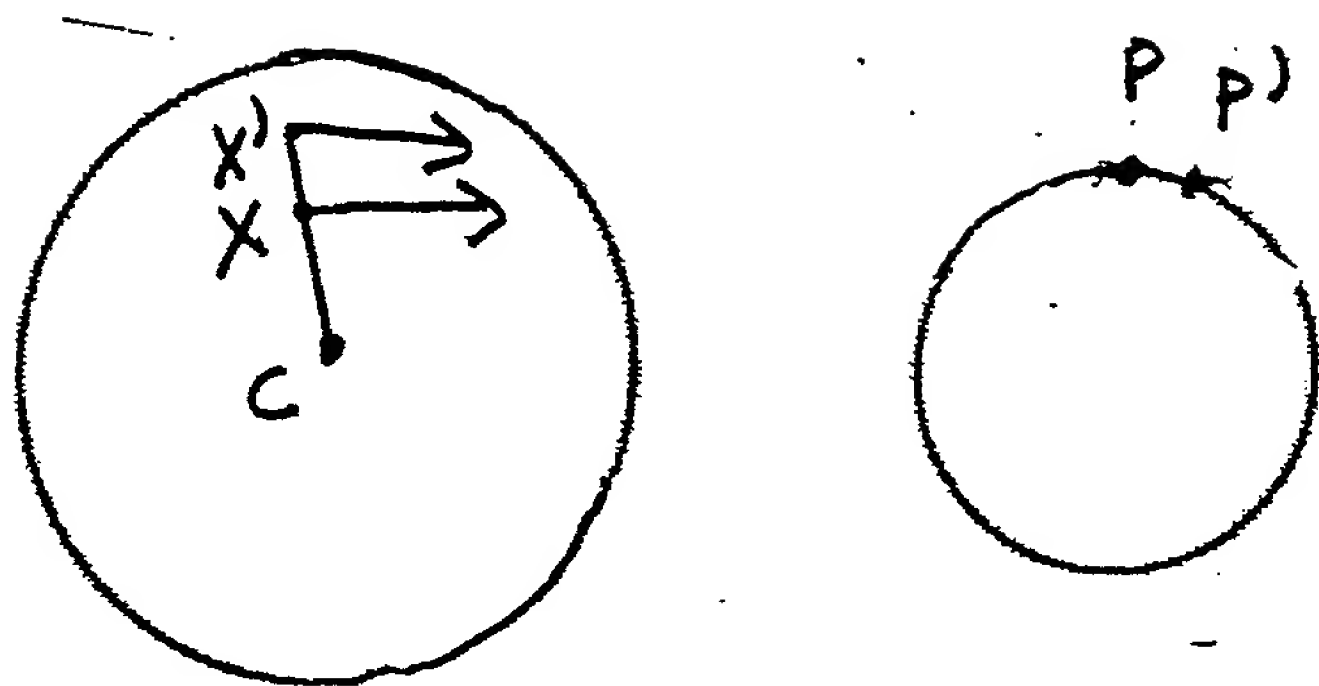


FIG. 9

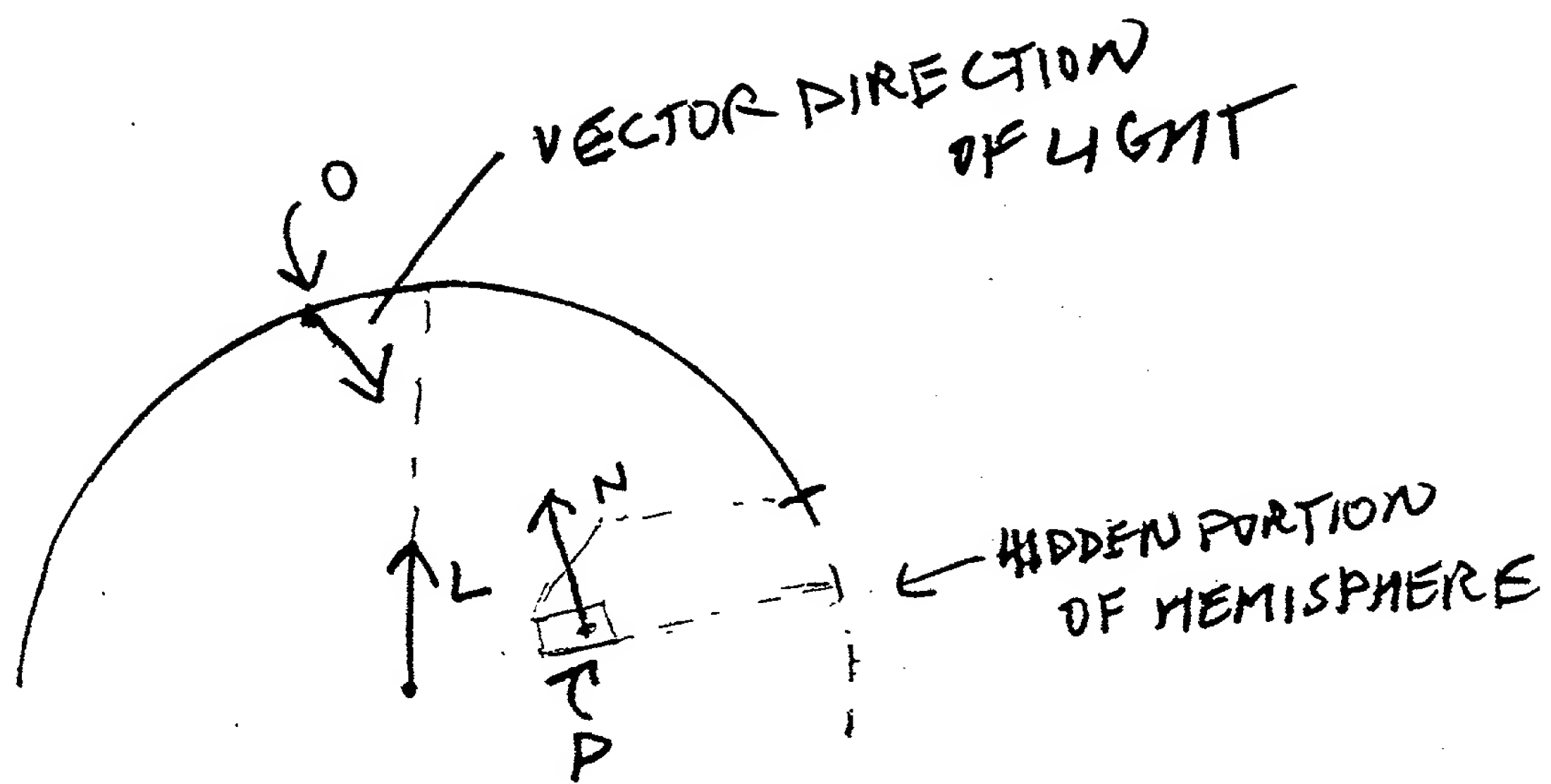


FIG. 10

**DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**

As below named inventor, I hereby declare that:

My residence address and citizenship is as stated below next my name.

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: PSEUDO AREA LIGHTS, the specification of which

 X is attached hereto.

 was filed on [date] as
Application Serial Number []
and was amended on [date].

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate, listed below and so identified, and I have also identified below any foreign application for patent or inventor's certificate on this invention filed by me or my legal representatives or assigns and having a filing date before that of the application on which priority is claimed.

Number	Country	Day/Month/ Year Filed	Priority Claimed - Yes or No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

Application Serial No.	Filing Date	Status

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorneys, with full power of substitution and revocation, to prosecute this application and to transact all business in the United States Patent and Trademark Office connected therewith and request that all correspondence and telephone calls in respect to this application be directed to McCUTCHEN, DOYLE, BROWN & ENERSEN, Three Embarcadero Center, San Francisco, California 94111, Telephone No. (415) 393-2000:

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Ronald S. Laurie	25,431
William W. Chuang	39,635
Nina K. Srejovic	40,342
Andrew Kumamoto	40,690
Joseph Yang	41,387
Michael Shuster	41,310
J. David Hadden	40,629
William E. Thomson	20,719

Full name of first
and sole inventor: Mitch Prater

Inventor's signature: _____ Date: _____

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